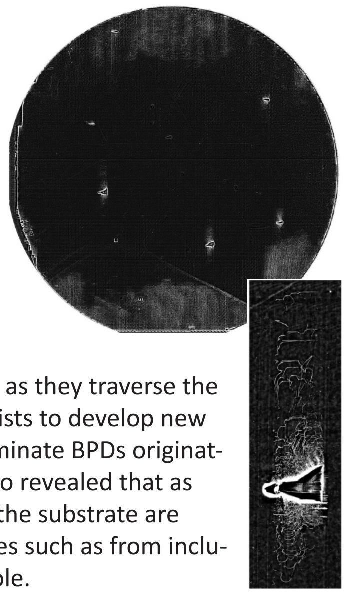
Advanced Characterization Techniques

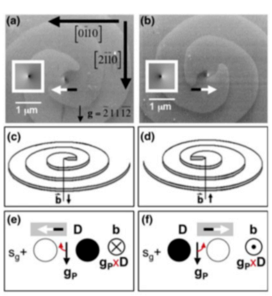
Basal Plane Dislocations in 4H-SiC Epitaxy — Looking Inside the Crystal

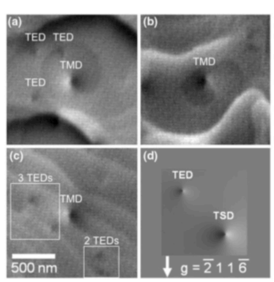


The suppression of basal plane dislocations (BPDs) in the epitaxy of 4H-SiC power devices is necessary for reliable and stable operation. The ultraviolet photoluminescence (UVPL) imaging technique developed in ESTD has provided a unique capability to nondestructively view all BPDs within the epitaxy across a whole wafer, as shown. The ability to track BPDs as they traverse the epitaxy has enabled ESTD scientists to develop new growth techniques to nearly eliminate BPDs originating from the substrate. It has also revealed that as BPDs entering the epitaxy from the substrate are eliminated, alternate BPD sources such as from inclusions start playing a dominate role.

Advances in Electron Microscopy: Electron Channeling Contrast Imaging (ECCI)

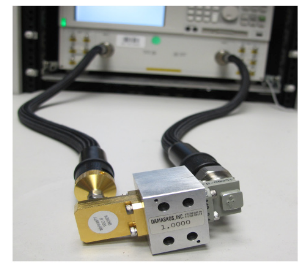
Diffraction contrast in transmission electron microscopy (TEM) provides the ability to trace the origin of a defect to errors in crystal growth — and thereby points the way to the elimination of defects that prove deleterious to device properties. The powerful diffraction contrast mechanism is no longer confined to TEM, however; ESTD has extended this approach to electron channeling contrast imaging (ECCI). Now, extended defects like dislocations and stacking faults can be analyzed at untreated GaN and SiC thin film surfaces in images that span hundreds of microns.





Dielectric and Magnetic Characterization of Materials in Ka-band and W-band Frequency Ranges

Complex permittivity (ε = ε′ − jε″) and complex permeability (μ = μ′ − jμ″) need to be known over a wide range of frequencies in order to explore the use of lossy dielectric and lossy magnetic composites to control RF oscillations, such as drive induced oscillations (DIOs), in microwave devices. Cold test measurements of lossy composites are made to determine the dielectric and magnetic characteristics in the Ka-band and W-band frequency ranges. Room-temperature and variable-temperature (from −180°C to 200°C) permittivity measurements of lossy composites have been performed. We have developed a two-port microwave reflection/transmission technique for broadband room temperature studies. Experimental measurements and simulation studies of materials with complex ε and μ have been performed to determine the unique characteristics of the material.



Magnetic Resonance Investigation of Defects and Recombination Processes in Semiconductors

ESTD employs several advanced spin resonance techniques to characterize and understand defects in semiconductor material systems. Electron paramagnetic resonance (EPR) is used to identify and quantify defect concentrations (including impurities and crystal imperfections) in bulk semiconductors, nanostructures, and interfaces. Optically detected magnetic resonance (ODMR) combines photoluminescence (PL) with EPR to identify defects involved in ra-diative recombination processes, while electrically detected magnetic resonance (EDMR) reveals defects that impact carrier transport in device structures.

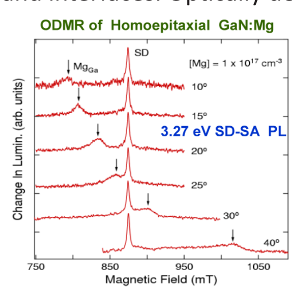


Figure: ODMR obtained on the 3.27 eV shallow donor–shallow acceptor PL band from Mg-doped GaN grown in ESTD.

SEM Real Color Cathode Luminescence

A new real color cathode luminescence imaging capability, recently installed in a LEO 435 vp SEM, was employed to evaluate the structural and optical properties of a selectively grown, periodically oriented homoepitaxial GaN film for nonlinear frequency conversion. This technique allowed a direct observation of dislocations in the substrates, their propagation and formation at the interface, and the uniformity of the domain boundaries. The difference in color at the epitaxial film and substrate regions is related to the dominant type of recombination processes associated with specific point defects.